IMPACT OF OFF-ROAD VEHICLES
ON THE AVIFAUNA
OF AFTON CANYON, CALIFORNIA

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ABSTRACT

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Two study plots were sampled 105 times each for avian abundance, variety, and distribution. One plot was in an area frequently used by off-road vehicles and was designated the high-use plot. The other plot was posted against entry by all vehicles and was designated the low-use plot. Sampling was performed from October 1977 to September 1978, both during periods when off-road vehicles were in use and during periods of little or no activity.

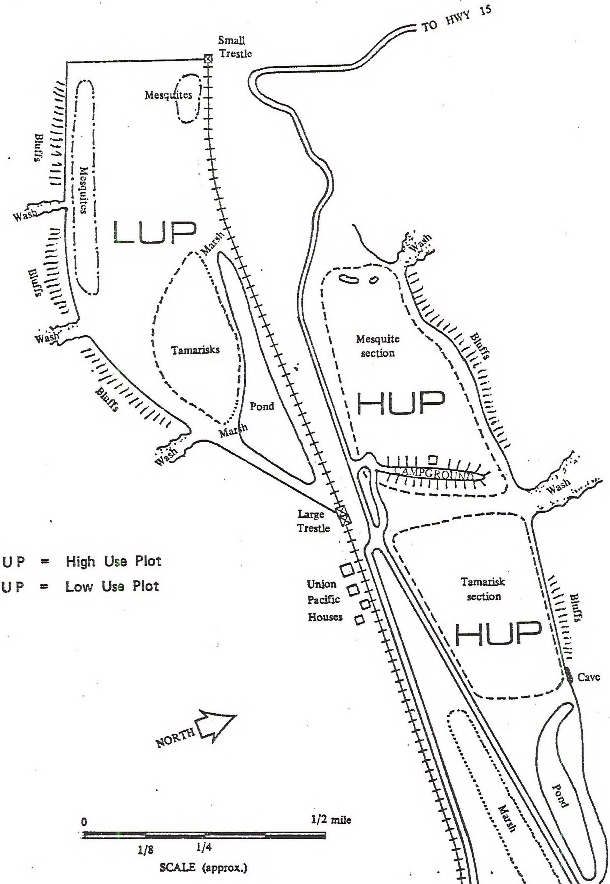
The data were analysed by t-tests which showed that there was a significant difference in bird variety and abundance between the two study plots. Within each study plot there was a significant difference in these parameters between days when off-road vehicles were in use and days when they were not. Canonical correlation showed that there was a marked tendency for most of the ten species analysed to move away from the area of off-road use, to flush more readily, or to perch in dense, thorny bushes.

INTRODUCTION

Afton Canyon is an oasis of riparian vegetation in the northeastern Mojave Desert, San Bernardino Co., California (Fig. 1). The floor of the canyon is essentially level and is surrounded by 200-foot high bluffs cut by numerous washes. An upwelling of the largely subterranean Mojave River creates several ponds and marshes. Access into the canyon is from Highway 15 via a gravel road which terminates in a Bureau of Land Management campground. A Union Pacific railway line runs the length of the canyon, and a group of buildings adjacent to the study plots houses Union Pacific maintenance crews and their families.

Since the establishment of the campground in 1968 recreational use has increased markedly, particularly the use of off-road vehicles. Previous studies have indicated many adverse effects of such human and vehicular use on the desert, in particular the compaction of soil (Wilshire and Nakata 1976; Wilshire et al. 1977; Wilshire et al. 1978), destruction of vegetation (Keefe and Berry 1973), and consequently, increased erosion (Wilshire and Nakata 1976; Wilshire et al. 1977). All of these effects may drastically alter the abundance and diversity of desert fauna (Busack, in Berry 1973; Berry 1973; Bury et al. 1977).

Most studies done so far, however, have dealt with the state of an ecosystem after a series of disturbances. This study examines birds on a daily basis, particularly fluctuations in their numbers before, during, and after a series of disturbances. Its purposes are 1) to determine the effects of recreational use, especially the use of off-road vehicles, on the abundance, variety, and distribution of birds within Afton Canyon, and 2) to correlate the size of the disturbance with the size of the effect it produces.



HUP = High Use Plot
LUP = Low Use Plot

Figure 1

Map of
AFTON CANYON
showing study plots

METHODS

Study Plots

Two study plots were established, each approximately 100 acres in area and similar in topography and vegetative composition. One of the plots was designated the low-use plot (LUP), where vehicular traffic was limited. The other plot was a high-use area (HUP), where vehicles were unrestricted, and where camping, hunting, fishing, and other recreational activities were practiced *ad libitum*.

The low-use plot is bounded on the north side by a levee containing the Union Pacific railroad tracks. On the south side is a bluff cut by several small washes. On the east side was a dense stand of tamarisks and reeds growing on a sand bar which dammed the waters of the Mojave River. This dam created the LUP pond until washed out by flooding in February and March, 1978. The west side of the plot was arbitrarily chosen to be a line drawn from the small trestle, perpendicular to the train tracks, and extending across the canyon floor to the edge of the bluffs in the south. This area was the only point of access for motor vehicles (until after the flood), and was posted with a sign at the gate by the trestle indicating that the area was closed to all vehicles. Four additional signs were posted around the perimeter of the plot, and thirty signs requesting visitors to refrain from entering the area at all were posted on the telephone poles alongside the railroad tracks.

The high-use plot was composed of three sub-plots: a mesquite section, a tamarisk section, and a pond-marsh section. The mesquite section is bounded on the south by the road connecting the canyon and Highway 15. On the north the section is bounded by bluffs rising sharply from the canyon floor. On the west are two large mounds covered with

desert pavement. On the east side is the campground, which was included in the section. The tamarisk section was bounded on the south by the Mojave River, on the north by bluffs, on the west by a line drawn from the large wash at the north end of the campground to the intersection of the road out to highway 15 and a road leading across the Mojave River to the Union Pacific houses. The eastern boundary is a line drawn from the cave in the bluffs to the road, perpendicular to the road. The pond-marsh section consisted of the pond and surrounding marshy areas, plus a strip of marsh in the bed of the Mojave River, running from the eastern tip of the pond to the eastern border of the tamarisk section. This pond was also washed out during the floods.

The area of each plot was determined by photocopying a U-2 photograph, enlarged to 21" by 21", cutting out each study plot, and weighing the pieces on a balance accurate to 0.0001g. A piece of known area was weighed to determine the scale. Each plot was found to be 101.9 acres (41.2 ha).

In both plots the canyon floor was essentially flat, 1400 feet above sea level. Approximately one-tenth of each plot was standing water which was surrounded by extensive marshy areas. Approximately half of each plot was bare ground (sand and rocks) throughout most of the year, but which was covered with a variety of annuals, particularly desert-sunflowers (*Geraea canescens*) and desert-marigolds (*Baileya pleniradiata*), during the spring. The other 40% of the plots was composed of perennial shrubs and trees, notably mesquite (*Prosopis glandulosa*, *P. pubescens*), tamarisk (*Tamarix aphylla*, *T. parvifolia*, *T. ramosissima*), cottonwood (*Populus fremontii*), willow (*Salix gooddingii*), desert willow (*Chilopsis linearis*), and catclaw (*Acacia greggii*). Other common plants include arrowweed (*Pluchea sericea*),

quail brush (Atriplex lentiformis), four-wing saltbush (A. canescans) allscale (A. polycarpa), creosote bush (Larrea tridentata), inkweed (Suaeda torreyana), yerba mansa (Anemopsis californica), salt grass (Distichlis spicata), common reed (Phragmites australis), palmate-leaved gourd (Cucurbita palmata), russian thistle (Salsola sp.), mormon tea (Ephedra sp.), beaver-tailed cactus (Opuntia basilaris), barrel cactus (Ferocactus acanthodes), fish-hook cactus (Mammillaria sp.), and several species of cholla (Opuntia sp.). In wetter places are found cat-tail (Typha angustifolia), hard-stem bulrush (Scirpus acutus), three-square (S. americanus), olney's bulrush (S. olneyi), basket rush (Juncus textilis), baltic rush (J. balticus), sea-purslane (Sesuvium verrucosum), chinese pusley (Heliotropum curassavicum), water parsnip (Berula erecta), mule fat (Baccharis glutinosa), desert panicum (Panicum urvilleanum), and sand dropseed (Sporabolus cryptanandrus).

Census

Each study plot was censused six times in December, January, and February; seven times in October; eight times in July; ten times in November, March, April, May, and June; and eleven times in August and September. The census period started within a half-hour of sunrise and lasted for five hours. A route was developed for each plot such that birds in any part of the plot could be seen or heard from some point of the census route. The method used was essentially a spot-map technique (Williams 1936) with minor variations. Since this was not a breeding-bird census, maps were not overlaid to determine territories or estimate numbers of singing males. Instead, the total number of birds detected anywhere within the boundaries of the plot were counted. In addition to recording the position of each bird observed, a notation was made of the type of vegetation the bird was in (if perched), or the direction of flight (if in the air). At the end of the census period the number of groups camped in the canyon, the number of dune buggies, trail bikes, and four-wheel drives

which were in operation in HUP, and the number of trains which passed through the canyon during the census period were noted. Off-road vehicles which were not in operation during the census period, or were not within the high-use plot, were not counted. If off-road vehicles were in operation in the low-use plot, no census was performed.

The data obtained during the census period in the above manner comprise the quantitative part of the study. They were analysed statistically, and form the bulk of this report. In addition, however, much qualitative information was obtained. On most census days several hours in the afternoon and evening were spent searching for migrants and for birds not normally active during the early morning hours (soaring birds, owls, goatsuckers, etc.), and also observing mammals, reptiles, amphibians, the activities of the campers, weather conditions, and other factors pertinent to the study. Nests were watched, photographs were taken, and the surrounding area was explored. Information gathered during these periods can be found in the problem section of this report and in the field notes (Appendix D).

Statistical Analysis

Each species recorded constitutes a dependent variable, as does the total number of species recorded per census. The number of individuals of that species is the size of the variable. The number of camper families, dune buggies and four-wheel drives, trail bikes, and trains, constitute the independent variables. Each census represents a case (or "individual"), thus, the total sample size for each plot is 105.

A t-test was used to test the null hypothesis (that is, that there is no significant difference between the groups). In terms of this study, that hypothesis is that the mean number of species recorded in each plot and the mean number of individuals in each plot are independent of the presence or absence of off-road vehicles. Also, that there was no significant difference between the high-use plot and the low-use plot based on the dependent variables. The Student's T-Test, as modified by R. A. Fisher (Li 1964), was used.

Ten variables (ten species of birds) were selected for more intensive study. The selection was based primarily on the results of a multivariate statistical procedure called discriminant analysis. The computer program DISANAL (Pimentel 1979), was used. Discriminant analysis is a method of comparing groups based on the simultaneous consideration of large numbers of variables. Group centroids are computed by averaging each of the n variables and plotting this point on an n-dimensional graph ("hyper-space"). Groups are seperated based on the euclidean distances between their centroids, and individuals are classified to the group whose centroid is closest.

The output from DISANAL which was used in the process of selecting variables for further analysis included the following: the means and standard deviations of each variable for each group; comparisons of the distances between each group based on each variable acting alone; discriminant vector coefficients and their direction cosigns (shows how each variable tends to seperate the groups); and the percentage of the variance of each variable in each canonical variate (shows the "power" or the ability of each variable to discriminate between the groups). Variables which had large means and small deviations (birds which were abundant and had little seasonal variation) were given priority. Of these, those which maximized distances between groups, had vector coefficients which tended to push groups in different directions, or accounted for high percentages of the variance, were given further consideration.

From the remaining variables ten were selected representing a cross-section of the major taxa in the area.

Two dissimilar sets of variables associated with each species were analyzed by CORANAL (Pimentel 1979), a computer program of canonical correlation. This procedure correlates variables of the first set with each variable of the second set, and calculates the strength of each correlation. The first set consisted of variables associated with the birds: TOTAL, the total number of birds of the target species found in LUP on the given day; MESQU, the percentage of the total number of birds found perched in mesquite; TAM, the percentage perched in tamarisks; WILLOW, the percentage perched in either willows or cottonwoods; FLIGHT, the percentage in flight; ZONE 1, the percentage of birds found in the zone of available habitat closest to the area where off-road vehicles were operating; ZONE 2, the percentage in the intermediate zone; and ZONE 3, the percentage in the available habitat furthest from the ORV area.

These variables were correlated to the variables in the second set, those associated with the environment: CAMPER, the total number of groups camped in HUP; DUNE B, the number of dune buggies and four-wheel drive vehicles; TBIKES, the number of trail bikes; and TRAINS, the number of trains passing through the canyon during the census period.

DISANAL was run in three parts, as the maximum number of variables allowed per run was 50. A separate run of CORANAL was made for each of the ten species. Both DISANAL and CORANAL were run on the IBM 360/40 computer at California Polytechnic State University, San Luis Obispo, California.

RESULTS

T-tests showed that there was a statistically significant difference at the 5% level between the high-use plot and the low-use plot, based on the number of species recorded per census. Also, there was a statistically significant difference within each plot between days when ORVs were being used in HUP and on days when no ORVs were in use.

Most importantly, there were fewer species of birds in the high-use plot than in the low-use plot (all days combined), and significantly fewer birds still, within the HUP, on heavy-use days compared to light-use days. Interestingly, there were more species in the LUP on heavy-use days than on light-use days (Table 1).

On the basis of the previously discussed DISANAL output, ten species of birds were selected for analysis by CORANAL, a computer program of canonical correlation. They were: American Kestrel, (*Falco sparverius*); Mourning Dove, (*Zenaida macroura*); Common Flicker, (*Colaptes auratus*); Western Kingbird, (*Tyrannus verticalis*); Say's Phoebe, (*Sayornis saya*); Verdin, (*Auriparus flaviceps*); Cedar Waxwing, (*Bombycilla cedrorum*); Western Meadowlark, (*Sturnella neglecta*); House Finch, (*Carpodacus mexicanus*); and White-crowned Sparrow, (*Zonotrichia leucophrys*).

To eliminate the problems of too large a variance, only data from the LUP was used for the analysis. If the data from both plots were combined, activity which might drive birds out of one plot might drive them into the other plot, thus cancelling out any correlation between the total number of birds and the number of ORV's. In addition, it would not be possible to divide the HUP into zones of varying distances from the ORV's, as the vehicles were usually spread out over the entire

TABLE 1

Group means (number of species per census) and t values for each t-test.

	HIGH-USE PLOT			LOW-USE PLOT					
	with orvs	no orvs	comb.	with orvs	no orvs	comb.	t value	df	sig
HUP	17.7	22.6					3.1	66	*
LUP				32.2	28.1		1.9	66	*
HUP vs. LUP			20.1			30.1	7.0	154	*

plot. However, any changes in behavior or distribution which can be established in the LUP, at some distance from the source of the disturbance, can probably be assumed to be occurring in the HUP as well, since it is much closer to the cause of the disturbance.

The results of CORANAL are summarized in Table 2. The complete output (including the output of DISANAL) can be found in Appendix B. The important parts of the output are the canonical vectors. One interprets them by comparing their values in set one to their values in set two. The magnitude of the number represents the strength of the correlation. The sign indicates whether the correlation is positive (direct), or negative (inverse). For instance, if a variable in set one has a high positive value for its canonical vector, and a second variable, in set two, has a high negative value, then it may be said that there is a strong inverse correlation between the two variables. If the two canonical vectors had had the same sign (either both positive or both negative), the correlation would have been positive. If either of the canonical vectors had had a small numerical value no matter how high the other one was, there would be no correlation between them. Intermediate values are indications of weak correlations.

The output of CORANAL gives several types of canonical vectors, the most meaningful of which is called the structure. Throughout the following discussion it should be kept clearly in mind that correlations only indicate relationships between variables. They do not necessarily imply a cause and effect relationship.

The results of the CORANAL for American Kestrel show that all of the values for set two are relatively high (0.500 or higher), and all are negative. Therefore, all of these variables are correlated to the high-valued variables in set one, and they are all producing the same kinds of effects. The highest value in this set is for trailbikes.

TABLE 2

Structure Values from CORANAL

SET 1	American Kestrel	Mourning Dove	Common Flicker	Western Kingbird
TOTAL	0.064	-0.425	-0.012	-0.687
MESQU	-0.878	0.197	0.192	0.308
TAM	0.062	-0.159	0.040	-0.191
WILLOW	0.532	0.089	0.475	0.183
FLIGHT	-0.316	-0.188	-0.591	-0.250
ZONE 1	0.579	0.700	0.019	0.526
ZONE 2	-0.153	0.690	0.662	-0.432
ZONE 3	-0.580	-0.844	-0.810	-0.056
SET 2				
CAMPER	-0.564	-0.798	-0.608	-0.919
DUNE B	-0.560	-0.955	-0.123	-0.725
TBIKES	-0.818	-0.868	-0.459	-0.563
TRAINS	-0.616	-0.188	-0.127	0.403

SET 1	Say's Phoebe	Western Meadowlark	House Finch	White-crowned Sparrow
TOTAL	0.642	-0.603	-0.508	0.654
MESQU	0.254	0.474	0.002	0.186
TAM	-0.509	0.494	-0.309	-0.117
WILLOW	-0.017	0.310	0.074	0.111
FLIGHT	0.067	-0.742	0.037	0.061
ZONE 1	-0.307	0.255	0.002	0.462
ZONE 2	0.409	-0.351	0.096	-0.026
ZONE 3	-0.091	0.227	-0.293	-0.302
SET 2				
CAMPER	-0.115	-0.851	0.442	-0.203
DUNE B	-0.245	-0.779	0.532	-0.238
TBIKES	-0.123	-0.881	0.333	-0.404
TRAINS	0.982	0.251	0.685	-0.837

0.300-0.500 (weakly correlated)
0.500-1.000 (strongly correlated)

The highest value in the first set is for MESQU, and it also has a negative sign. Thus, the strongest correlation is between the number of trailbikes in the HUP and the percentage of the kestrels which are perched in mesquite. It is a positive correlation: the more trailbikes there are, the more likely the kestrels are to be perched in mesquite. It is important to note that the opposite is also true. When there are few trailbikes in the HUP kestrels are less likely to be perched in mesquite. Note also that the correlations for dune buggies, trains and campers are also strong and positive. American Kestrels are reacting to all of these variables in a similar manner. There is also a strong negative correlation between all of the set two variables and WILLOW. This indicates that kestrels are less likely to perch in willows and cottonwoods when trailbikes and the other factors are in the HUP. Zones 1 and 3 were also strongly correlate with the set two variables. Zone 1 is negatively correlated, and Zone 3 is positively correlated. Therefore, kestrels are less likely to be found in Zone 1 and more likely to be found in Zone 3 when ORV's, trains, and campers are abundant in the HUP. The percentage of kestrels in Zone 2 is unaffected by the set two variables. The total number of kestrels, the percentage perched in tamarisks, and the percentage in flight also failed to correlate to any of set two variables.

The results for Mourning Doves are similar, except that trains were not important, and neither were any of the plant variables. But the correlations between trailbikes, dune buggies, and campers, and the three zones were very strong. Again, the high values and opposite signs of the set two variables with Zones 1 and 2 indicate a strong tendency of the doves to be less numerous in those zones during heavy-use periods in the HUP. On the other hand, the high positive correlation with Zone 3 indicates an increase in the number of Mourning Doves in that zone during these periods. The total number of doves in the study plot was only weakly correlated to the set two variables.

For Common Flickers two CORANALs were run. After an initial run with only twenty cases, four additional cases were added to bring the total sample size up to the level of the other species. Because flickers were present in LUP on relatively few occasions, this necessitated using data from "marginal" days, when either few ORV's or few flickers were present. This caused a loss of correlations, as can be seen by the fact that no correlations in the second set were higher than 0.400 (Appendix B). This is too low to be interpretable. However the original, which is shown in Table 2, run with 20 cases, shows good correlations of campers and trail-bikes in set two with the percentage of birds in flight and in Zones 2 and 3. The more campers and trailbikes there were in the HUP the more likely flickers were to be in flight, and the more likely they were to be in Zone 3 than in Zone 2.

In the case of Western Kingbirds all the set two variables had high negative canonical vectors, except for trains, which had only a weak correlation with the set one variables. In set one, the highest correlation was with the total number of kingbirds in the LUP, and it was a positive correlation. The more ORV's and people there were in HUP, the more kingbirds there were in the LUP. None of the plant variables showed strong correlations, but Zone 1 was strongly inversely correlated. Zone 2 is weakly positively correlated, showing that when ORV's and people increase in HUP the percentage of Kingbirds in Zone 1 decreases and the percentage in Zone 2 increases. Zone 3 does not change.

The output for Say's Phoebe shows what are called "spurious correlations". Most of the original values are very low, which forces the relatively higher ones, after the processes of standardization and normalization, to be numerically quite high. However, they are much higher than

they should be. They do not make any kind of biological sense, and are not interpretable. It should be noted that in a set of ten correlations, each at the 5% level of significance, the confidence level becomes (0.95) exp. 10, or 0.60. This means that there is a 40% chance of error in this series (which is one of the main problems with multiple correlations).

In the CORANAL results for Western Meadowlarks all the set two variables except trains had high negative values. These correlated positively with the total number of birds--the more ORVs and people in the HUP, the more meadowlarks in the LUP. None of the plants correlated strongly, but all were weakly correlated inversely. That is, they were less likely to be perched at all when ORVs were in the HUP. This is reinforced by the fact that there was a strong positive correlation between the set two variables and flight. Meadowlarks tended to spend more time in flight at these times. None of the three zones were correlated strongly to any of the set two variables.

All of the House Finch values are low except for a weak correlation between the total number of birds and the set two variables. This is a negative correlation, meaning that there tended to be fewer House Finches in the LUP when there were ORVs, people, and trains in the HUP.

A similar situation is reflected in the White-crowned Sparrow results. Trailbikes and trains correlated inversely with the total number of birds. However, an important difference between this data and that of the House Finches should be noted. In the White-crowned Sparrow results there is also a weak correlation with Zone 1, and to a lesser extent, with Zone 3. The correlation with Zone 1 is negative, implying that fewer birds are in this zone when trailbikes and trains are around. The Zone 3 correlation is positive, showing a trend of increasing numbers of sparrows under these conditions.

The CORANALs for Cedar Waxwings and Verdins did not run at all due to the fact that some of the variable did not vary. Constants cause mathematical impossibilities (dividing by zero) within the program. Both species are so closely tied to mesquite that the other plant variables did not vary, so that the programs aborted.

DISCUSSION

The t-tests showed that the area open to off-road vehicle use generally supported fewer species and lower numbers of birds than a similar nearby area which was closed to all vehicles. This was the case even on days when no ORVs were in use. There was a further decrease in these numbers on days when vehicles were in operation, implying that some birds were driven out during these periods. A corresponding increase in both variety and abundance in the closed area indicates that some or all of these birds took refuge in the LUP. That the HUP should support fewer birds on both heavy- and light-use days suggests both short-term and long-term effects on the area as a suitable habitat for birds.

Both of these possible effects are given additional support by the results of the canonical correlations. In addition, these data give detailed information on how different species react to ORVs, trains, and people.

American Kestrels reacted strongly to all four types of human activities, and reacted in two basic ways. First, they tended to leave willow and cottonwood trees, perching instead in mesquites. The implication is that the dense and thorny mesquites give better cover than the more open willows and cottonwoods. More importantly, the negative correlation between ORVs and willows indicates that, when ORVs are not influencing their behavior, kestrels prefer to perch in the taller, more open willows and cottonwoods. Kestrels do a large proportion of their hunting from a perch (Bent 1938); a tall, open tree would appear to be more suitable for this purpose than a low, dense bush. ORVs campers, and trains apparently cause kestrels to change to a less desirable perch, perhaps interfering with their ability to hunt for food.

The other reaction of kestrels to the set two variables was to move from Zone 1 (an area only a few hundred yards from the open area) to Zone 3 (one-half to one mile from the nearest ORV area). Again, the implication is that the birds felt threatened when close to areas of human activity and noise, and when humans were not around, they preferred to be in Zone 1.

A conspicuous lack of correlation (in the light of the other species tested) occurred with the total number of American Kestrels in the LUP. Since kestrels are territorial throughout the year, it is not too surprising that kestrels from other parts of the canyon did not leave their territories to come into the LUP. If they had, they would probably have been chased off, as kestrels and other raptors spend much of their time driving off intruders from their territory (Bent 1937). The fact that kestrels in the LUP move away from the source of the disturbances to a distance of half a mile or more poses the question of what happens to the kestrels in the HUP, which perhaps cannot find acceptable unoccupied habitat free from ORVs.

Mourning Doves showed an even stronger tendency to move away from people and ORVs (trains are apparently not a factor). In their case, not only were the numbers higher, but both Zones 1 and 2 showed decreased numbers, and a big increase in Zone 3. Of all the species tested, Mourning Doves showed the strongest response against ORVs and people. On the other hand, they showed no tendency to change their perch habits on heavy-use days. Apparently their strategy during periods of human encroachment is simply to move far enough away from it that it is no longer a disturbance. Not surprisingly, there was also a positive correlation to the total number of Mourning Doves, the excess presumably coming from the HUP or other parts of the canyon where ORVs were being used.

Common Flickers also showed a tendency to move into Zone 3, primarily from Zone 2. There was little drop in the percentage of flickers in Zone 1. Several explanations for this are possible. In the first place, Zone 1 included nearly all of the willows and cottonwoods, the flickers' most preferred perch trees. It may be that they were reluctant to leave them for the tamarisks of Zone 2, after the willows of Zone 3 had already been taken. This idea is supported by the fact that the percentage of flickers perched in willows or cottonwoods decreased, but none of the other plant species showed a corresponding increase. Only FLIGHT shows this increase, suggesting that some of the flickers tried to stay in the Zone 1 willows, but were continually being flushed out of the trees by the activities taking place nearby. An alternate explanation is that flickers already in the LUP moved over to Zone 3 and beyond, where more good-sized trees could be found. Flickers in the HUP moved into the LUP, finding available habitat only in Zone 1. The influx of HUP birds into Zone 1 would disguise the exodus of LUP flickers from there. If this is the case, and some of the LUP flickers did move beyond the LUP boundaries, it would explain the otherwise puzzling lack of increase in the total number of birds in the LUP.

Western Kingbirds showed a tendency to move from Zone 1 to Zone 2, but no farther. The "radius of disturbance" of ORVs and campers is therefore smaller for kingbirds than for kestrels, Mourning Doves, or flickers, though the tendency to move away is still fairly strong. There was also a very strong correlation to the total number of kingbirds, indicating an influx of birds from other parts of the canyon. As with Mourning Doves, there was no change in perching habits due to the ORVs.

Western Meadowlarks show a quite different pattern. While campers, dune buggies, and trailbikes again showed high vector coefficients, the correlations with the different zones were uniformly low.

Also, in spite of a strong tendency for the total number of meadowlarks to increase, every plant variable showed decreases with increased ORV activity. The explanation is rather simple, however. Though some of the birds were recorded as in flight, most of the increase was probably in birds standing on the ground, a category not included in the data, but one which was very important for meadowlarks which are basically ground-feeding birds. The meadowlark strategy, therefore, seems to be to move a short distance (from the HUP to the LUP), either standing on the ground or flying. When they are on the ground they are often less visible (to humans) than when they are perched, so the grass may actually give them better cover.

The results for House Finches are totally opposite to most of the other species. Most of the correlations were low, but there were weak inverse correlations with three variables: TOTAL, TAM, and ZONE 3. The negative correlations with the total number of finches and with Zone 3 indicates that these birds are moving toward the human activities, rather than away from it, as in all the other species. The reason for this may have to do with the niche occupied by House Finches. These birds are basically urban and suburban birds, adapted to the largely unfilled niche of human-tolerant species, living off human garbage and enjoying the benefits of an environment with fewer predators. If House Finches are indeed deriving benefits from their association with people, then it is perhaps logical that they should be attracted to their sounds in an area of only sporadic human occupation.

White-crowned Sparrows showed movement from Zone 1 to Zone 3, but they also showed a decrease in the total number of birds present. Unlike House Finches, however, it is unlikely that this decreased total is the result of birds being attracted to the ORV activity. Because, unlike the House Finches, the correlations of the three zones indicates that there is movement, within the LUP, away from the ORVs.

Therefore, if birds are leaving the plot, it is more likely that they are leaving it from the far side, rather than going into the HUP. If this is true, White-crowned Sparrows may have an even greater "radius of disturbance" than Mourning Doves. Both they and Common Flickers give evidence of being driven more than a mile away from the source of the noise.

General patterns emerge from these seven individual reactions to human recreational use. If we apply these patterns to the hypothesis that ORVs are disruptive to birds, we can test the hypothesis in several ways. For example, if ORVs are disruptive, we would expect that the total number of birds of a given species in the LUP to increase as the total number of ORVs in the HUP increase. In fact, this was the case in 43% of the species studied. There were four species for which it was not true: American Kestrels, which are territorial; Common Flickers and White-crowned Sparrows, which may have moved so far from the ORVs that they moved out of the count area; and House Finches, which are urban-adapted. Of the species tested, only the House Finches actually decreased in number.

If the hypothesis is true we might also expect an increase in birds perched in mesquite or in flight, and decreases in tamarisks and willows. In fact, 43% showed the expected increases, and the other species simply had values too low to correlate. In only one case (the ground-feeding Western Meadowlarks) did mesquite decrease, and in no case did tamarisks or willows increase.

Sixty-seven percent of the species showed the expected decrease in Zone 1 during ORV activity. No species increased in Zone 1. Also, 67% showed the expected increase in Zone 3. Only a weak decrease in House Finches went counter to the hypothesis.

In every case the set two variables campers, dune buggies, and trailbikes had the same sign, showing that they were all producing the same kind of effects on the birds. Trains, which were important in only three species, were exceptions to this twice, but both times the values were too low to be considered correlations at all. The implication is that not all bird species react to trains in the same way that they do to ORVs.

Taken all together, the data show a consistent pattern of birds moving away from ORVs, even within the protected confines of the closed area, in most cases as far as the available habitat permits. For most species this is 1/2 to 1 mile (Zone 3). In the cases of Common Flickers and White-crowned Sparrows the data suggest that they may be moving even further than one mile. There is also a clear trend of disruption of perching behavior, either changing the perch plant from willows and cottonwoods to mesquites, or abandoning the perch entirely, flushing easily and repeatedly throughout the census period.

Both of these trends may create problems for the well-being of the birds. The movement of birds away from a disturbing factor is not always possible. As in the case of the American Kestrel, some birds are territorial throughout the year. In addition, almost all birds are territorial during the breeding season. Often nest sites are chosen rapidly (especially by non-residents), but are clung to tenaciously. If a nest is chosen during the week in an area which proves to be an ORV area on the weekend, some birds may attempt to remain with the nest, thereby losing their mobility. What effect this may have on reproduction or the ability to feed the young is not known. Even in more mobile birds, the ability to get away from ORVs may be limited by the extent of suitable habitat and the extent of the ORV use. Water and marsh birds, for example, may be unable to find suitable habitat outside Afton Canyon, for many miles in any direction. Since ponds are attractive areas for camping, picnicking,

hunting, and fishing, these birds may not find it easy to avoid ORV's anywhere in the northeastern Mojave Desert.

The other pattern, that of changing perch plants and spending more time in the air, may also cause problems. As with American Kestrels, there may be advantages in selecting one plant over another: advantages in hunting, feeding, or securing a better vantage point or song post. Changing perch plants may therefore put the bird at a disadvantage in these important areas for the period of time which it spends on the secondary vegetation. Spending more time in flight is disruptive of many activities, such as feeding, resting, singing, courting, and incubating eggs. An increase in the time spent in the air suggests a corresponding decrease in these activites. Also, small birds are more subject to predation when they are in flight, particularly from Prairie Falcons, (*Falco mexicanus*); Cooper's Hawks, (*Accipiter cooperii*); and Sharp-shinned Hawks, (*A. striatus*), (Bent 1938), all of which are found in Afton Canyon. They may also inadvertently attract attention to themselves while in flight, and when they again come to rest may be found more easily by other predatory birds and mammals.

RELATED PROBLEMS

The foregoing represents the quantitative results of the information obtained during the year of data collection. During this year many other aspects of the impact of recreation on the wildlife of Afton Canyon were noted, albeit in a strictly qualitative way. The following, therefore, represent observations, thoughts, and additional or future problems in Afton Canyon.

The study itself dealt exclusively with the present distribution and abundance of birds in the canyon. It does not show what species might have been present if there had not been off-road vehicles in the canyon for the last ten years. Although all efforts to obtain field notes from Afton Canyon prior to 1968, were unsuccessful, an article by Edmund C. Jaeger in Desert Magazine (Jaeger 1957), mentions, in a list of less than twenty birds, two species not now found in the canyon: the Wood Ibis (*Mycteria americana*) and the White-faced Ibis (*Plegadis chihi*). It is not known how many other species common twenty years ago are not found there now.

One effect of ORV activity is to drive birds away. That is not the only possible effect, however. For example, the noise itself apparently causes shock to some animals, in some cases resulting in their death. Studies of the effect of snowmobile noise on elk have shown that "it is not weakness or attempted escape that causes the animals to drop to the ground; it is shock caused by extreme stress" (Baldwin and Stoddard 1973). Dead birds would not show up in the data of a study like the present one. The extent of these deaths by noise-related stress is therefore not known. Also hard to judge quantitatively are breeding disruptions. Disruptions of breeding patterns, decreased clutch size, decreased fertility, decreased ability to feed young, and increased mortality are all potential dangers, the extent of which are not known.

The carrying capacity of predators may also be lowered as a result of ORV activity. Studies have shown an eight-fold decrease in small mammal population densities in ORV areas (Hicks et al. 1976), and a similar decrease among lizard populations (Busack 1973). Predatory birds with large territories, such as eagles, hawks, and owls, could be expected to suffer from losses of food items, though not always in ways likely to be revealed in this type of study.

Another aspect of the noise generated by ORVs relates to the fact that birds were observed during the course of the study to fly at the sound of the approach of vehicles, even if the vehicles were at a considerable distance, and even if they were out of sight. This causes them to abandon the concealing vegetation and may result in increased predation upon small birds, especially migrants and transients, which are especially likely to flush.

In addition, the constant high noise levels in heavily used areas can interfere with the communications between birds. Birds are, in general, highly vocal, and these vocalizations are important in many ways. During the breeding season territories are established and maintained by almost constant singing, and females are courted through song. At all times of the year calls serve to give warnings, keep flocks together, express moods, serve as recognition signals between mates, offspring, and members of a social group, and many other important functions (Welty 1975). Any or all of these functions may be disrupted by ORV noise.

It should be mentioned, however, that it is not simply a matter of noise or movement which causes the problems. Some disturbances of this kind can be adjusted to. For example, during the process of sampling the LUP pond in the winter, when a constant stream of different species of waterfowl came through the area, it was noted that new arrivals flushed from the marsh each time a train went by. After a day

or two, however, the trains were largely ignored. It therefore became easy to distinguish between new arrivals and those which had been there for several days. Some type of learned tolerance was apparently taking place. This reached its culmination when a pair of Say's Phoebes nested on one of the girders supporting the train tracks on a trestle east of the study plots. Two clutches of eggs were hatched and fledged from this nest, only inches below the tracks. Fifteen or twenty times per day trains passed overhead, but the phoebes were apparently able to adjust to this; however, observations showed that they still flew at the approach of ORVs. Possibly the predictability of the trains, which were localized (restricted to unchanging corridors), and were fairly regular throughout the day and week, makes them more easily adjusted to than the ORVs, which tend to come in swarms and are unpredictable in their paths. Perhaps they have simply learned that trains do not cause problems, while ORVs sometimes do. This is certainly not beyond the capacities of birds, as Red-tailed Hawks quickly learn that moving cars along a road are no threat, even when they pass directly below the bird at high speed; but if the car stops or even slows down, the hawk is likely to fly. Birds certainly can learn from experience.

The above problems are all concerned with the immediate effects of ORV activity. There are also long-term effects, which were beyond the scope of the present study, but whose effects can perhaps be hypothesized. For instance, several studies (Wilshire and Nakata 1976; Wilshire et al. 1977; Wilshire et al. 1978) have shown that ORV activity has a deterimental effect on the quality of the soil. "Soil compaction is the dominant consequence of motorcycle use. Combined with the fact that vehicle use has denuded the surfaces of much plant cover, and has stripped the protective desert pavement, motorcycle use has caused a significant potential for erosion" (Wilshire and Nakata 1976). This damaged soil, denuded of vegetation, will remain without vegetation for long periods. Tracks fifty to one-hundred years old, and century-old Indian intaglios

remain virtually unchanged, and are commonplace in the Mojave. "Archeological rock formations, constructed like the intaglios by scraping pebbles into windrows, have survived approximately 1000 years of exposure..." (Wilshire and Nakata 1976). Where there is no vegetation there is little wildlife. In turn, the loss of wildlife (particularly the burrowers, who aerate the soil, the pollinators, the seed-dispersal agents, and the fertilizers) makes it all the more difficult for the vegetation to become reestablished. This causes the problem to remain long after the original cause has passed. As the soil quality and the vegetation decrease, the bird life can be expected to decrease, both in variety and abundance.

To make matters worse, Wilshire and others have found that the effects often spread to neighboring areas. In their words, "Erosional effects have not been effectively contained within the boundaries of any site that we have examined" (Wilshire et al. 1977). Creating small restricted areas near ORV sites as "preserves" would probably be an inadequate measure.

Other long-term effects involve gradual losses (through many of the factors discussed above) of residents, nesters, and eventually, even migrants. As the number of residents decline, the process can be expected to be accelerated by the invasion of "weedy" species, such as the non-native Starlings (Sturnus vulgaris) and House Sparrows (Passer domesticus), which are already found here in limited numbers. These species tend to drive out native species, flooding an area with large numbers of birds of only a few different species.

The use of campfires is potentially a severe long-term problem. Few visitors bring their own wood, so most fires are made from mesquite, the most handy and satisfactory wood available. Both dead and living trees are utilized. In addition to being a protected plant, mesquite is an important type of vegetation for the birds. Cover, perches,

is an important type of vegetation for the birds. Cover, perches, roosts and nests are more often in mesquite than in any other plant in the canyon. Many times I have observed White-crowned Sparrows, when disturbed, to fly directly towards and around the disturbance, in order to get to a mesquite bush, rather than fly away from the disturbance to some less-preferred type of cover. Indeed, some species like Verdin, Cedar Waxwings, and especially Phainopeplas (Phainopepla nitens), are rarely or never observed in any other type of vegetation. Though mesquite is protected, the responsible agency (California Department of Fish and Game) does not have the manpower to enforce the restrictions, and there are currently no signs in Afton Canyon stating that it is illegal to burn mesquite.

This is a serious problem in Afton Canyon for several reasons. In the first place, the amount of wood burned on an average weekend is significant in relation to the total amount of wood there. Mesquite only grows in the flat areas near the Mojave River, usually near cliffs or rocky areas. This limited distribution makes the plant scarce even in the canyon, and non-existent in the creosote-scrub areas which make up the bulk of the desert in this area. Mesquite is also slow-growing. It may therefore be burned faster than it is being replaced by growth. These factors combine to suggest a significant loss of habitat in a few year's time. Secondly, in a dry and windy area like Afton Canyon, the risk of brush fires is high. In the summer of 1978 four brush fires occurred in the area surrounding the campground, three of them from illegal campfires. This further reduces the amount of vegetation.

Many ORV-users utilize their off-road capabilities to camp outside the campgrounds, creating large clearings, fire-pit scars, increased fire hazards, and litter problems. Litter is also a problem around the railroad tracks. Many Union Pacific employees simply throw broken or used equipment of to one side. Rusty train parts, such as brakes, lights, fire-extin-

guishers, and various unidentified scraps of metal can be found throughout the area. At one spot in the LUP there is a pile of a dozen 55-gallon drums, empties of the track and flange grease which is put into a reservoir nearby (see picture 46, Appendix A). This litter is unsightly, but more importantly, residual oil may harm curious animals who may explore the barrels for nesting sites, roosts, or cover. Such an oiled bird or mammal may in turn pass the oil on to a larger predator.

Shooting is also a problem Although shooting is prohibited within one-half mile of the campground, the vast majority occurs within a hundred yards of it, or actually within it. Several times I was sprayed with spent shot or narrowly missed by rifle bullets. A quiet person on one side of the thicket is a potential recipient of the shot from the unthinking or incautious shooter on the other. The sight of a person sitting in a dune buggy, rifle in one hand, can of beer in the other, is common sight around the campground. The litter of spent shells can be seen nearly everywhere, and many non-game species can be found dead, shot after a weekend of "target shooting" (see pictures 39 and 40, Appendix A). Since nearly all of the easily accessible floor of the canyon is within the half mile restricted zone, most of the shooting occurs in this area. The shot-up signs and beer cans, as well as the litter of shells, attest to this. Since there is no ranger present, people simply tend to ignore the restrictions, and illegal hunting (hunting out of season or hunting non-game species) is common.

Many of the foregoing problems may be the result, to some degree, of the lack of supervision and enforcement of rules. In a year of residence, Bureau of Land Management rangers were seen only about half a dozen times, and never on the weekend. There is a sign at the entrance to the campground (picture 18, Appendix A) with five rules on it. Not a single weekend went by without most, if not all, of these rules being broken, and

usually by the vast majority of the campers. Most of the signs I put up in the LUP were ripped down, shot up, driven over, or defaced, and all were ignored. The impression one gets after a year of almost daily contact is not that of a "few bad apples" constituting a "tiny fraction" of ORV-users, but rather of a sizable majority, who are steadily, knowingly, and belligerently running roughshod over the area. Discussions with rock-hounds, birders, botanists, biology classes, and similar visitors have pointed up the basic incompatability of ORV use with nearly any other type of activity. Nearly all activities other than off-roading are currently restricted to those who can come during the week. On the weekend, few animals and few people, other than off-roaders, can stand to be in the canyon.

CONCLUSION

Recreational use, particularly the use of off-road vehicles, has had an adverse effect on the avifauna of Afton Canyon. This is reflected in both species variety and abundance of individuals, and is true both in a high-use area and in a nearby restricted area.

It has been shown that birds tend to leave areas of high ORV use, moving away from the disturbance as far as the available habitat permits. Birds tend to flush more readily or seek the protection of thorny bushes, even at considerable distances from the site of the disturbance.

The radius of disturbance from off-road vehicles has been shown to be one-half to one mile for most species, and may be greater for others.